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GRAPHITE AT HIGH TEMPERATURES

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Investigating Heat-and Electro-Conduction of Tungsten and Graphite at High Temperatures

(ISSLEDOVANIYE TEPLO-i ELEKTROPROVODNOSTI VOL'FRAMA i GRAFITA PRI VYSOKIKH TEMPERATURAKH)

by

V.S.Gumenyuk and V.V.Lebedev

In this report is described the installation (experimental) built for the purpose of determining the coefficient of heat conduction, electro conduction and their ratios for metals and alloys in the field of high temperatures (900 - 2200° C). Data are presented on the temperature dependence of heat conduc tion and specific electric resistance of tungsten and graphite, and given are also the values of the Wiedeman-Frantz ratio in a wide range of temperatures. Empirical formulas are presented to calculate the heat conduction of tungsten and graphite in relation to temperature. A comparison was made with the avail able literature data.

Dta on heat conduction and electro conduction of metals and alloys have greater applied and theoretical value. They appear to be fundamental for sol ving numerous problems pertaining to the physics of metals. Of considerable in terest are the investigationsof metals in the field of high temperatures. But up until now there are only few counted reports on the heat conduction of high melting metals. The values of the thermal constants at high temperatures, ob tained by various authors, show considerable dicrepancies, and in many instan ces they plainly contradict each other.

Table 1 contains available literature values for heat conduction of tung sten. According to data by Worting,Swicker and Forsyte [1] the coefficient of

of heat conduction W in the range of 1000 - 2200 C rises slowly with temperature. A much recent investigation,carried out by Osborn[2] shows a different dependence of heat conduction upon temperature. In many other literature sources[3,4] are given values, which differ by a full magnitude from the data of above mentioned authors.

Table 1.

Literature source	Heat conduction of Tungsten (cal/cm.degr.sec) at temperatures ($^\circ$C)						
	1000	1200	1400	1600	1800	2000	2200
Worting	0.220	0.223	0.255	0.279	0.303	0.327	0.349
Swicker	—	—	—	0.298	0.312	0.324	0.331
Worting-Forsyte	—	0.236	0.247	0.259	0.268	0.278	0.288
Osborn	0.273	0.266	0.258	0.251	—	—	—
Technology of higher temperatures	3.79	—	—	—	—	4.90	—

The purpose of this investigation is to study the temperature dependence of the coefficient of heat conduction and specific electric resistance of tungsten and graphite in a temperature range of 900-2200 C.

Investigation Method

To determine heat conduction coefficient was employed a method,described by us previously[5] . If a short and long rod of one and the same diameter and chemical composition are heated with electric current in vacuo to an identical temperature then for heating the short rod (on account of additional heat loss at the tips) requires higher amperage. On the basis of this it is possible to compute the heat conduction of thematerial:

$$\lambda = \frac{\rho x^2 \left(I^2 - I_1^2 \right)}{2 S^2 \Delta T}, \qquad (a)$$

where λ - coefficient of heat conduction; ρ - specific electric resistance; S - transversse cross sectional are of samples; ΔT - temperature differential along the length x, I-amperage necessary for heating the short rod, and I_1 -

for heating the long sample.

In this way to determine lambda it isnecessary on the lengthy sample to measure rho and I_1, and on the short one – I and $\triangle T$ as a function of x.

Figure 1.

Fig.2.Temperature distribution near the center of the short tungsten sample; 1-temperature at center 1600 ; 2- 1400 3-1600 C.

For measuring these values was constructed a special installation. Species of the investigated material were fastened in water cooled clamps,one of which could shift around freely under the effect of thermal expansion of the investigated bar Because of this arrangement deformation of the sample in the process of experimen tation was practically eliminated. The spacing between the clamps could vary in wide intervals (from 0 to 150 mm). To the sample were applied two molybdenum or tungsten probes which allowed to measure voltage drop at definite distance. This entire system in vertical arrangement was situated in a vacuum chamber the working vacuum in which was no lower than $1 \cdot 10^{-5}$ mm Hg.

To determine voltage and amperage drop the P-56 type AC potentiometer was used. The tenperature was measured with the OFPIR-09 optical pyrometer which was rigidly fixed to the trolley of KM-6 cathetometer (fig.1). This enabled to use
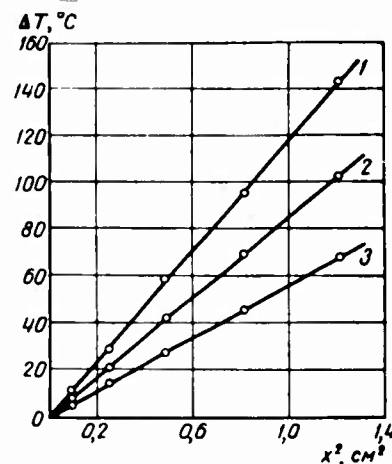
the cathetometer scale during the measurement of temperature distribution along

the sample and during the determination of distance between probes as well.

To increase the temperature measuring accuracy the pyrometer was reconstructed

somewhat. The voltage drop on the pyrometer tube was measured by the compensation

method with the aid of a potentiometer. In addition a thorough calibration was

made over the entire range of temperatures up to the point of absolutely black

body, the temperature of which was measured up to 1500 with a platinorhodium-plat

inum thermo couple, and at much higher temperatures with the TSNIICHM-1 thermo

couple.

Voltage stabilization was realized by means of a specially developed stabi

lizer on the basic of AOSK-10/05 auto-transformer.

On the short sample near the center the temperature distribution is subject

to parabolic law 6 . In our own case 5

$$\Delta T = \frac{1}{2} f(t) x^2. \qquad (4)$$

Consequently, to determine the heat conduction coefficient it was sufficient

to plot the dependence T upon x^2 and by the tangent of the angle of inclination of

the straight line to determine $f(t)$, and then compute the magnitude lambda. As

is evident from fig.2, the experimental points are well disposed on the straight

line, which confirms the square dependence of temperature upon the coordinates .

Such a method of determining temperature differential ΔT raises to a large ex-

tent the measuring accuracy. The error of measuring lambda does not exceed 6%.

In the role of investigated materials was selected spectrally pure graphi

te and tungsten wire with diameter of 1 to 2.2 mm. The species after preparation

were precalcined in high vacuum at temperature of 1700°C for a period of 1 hr.

Measurement Results.

The temperature dependence of the coefficient of heat conduction and specific electric resistance of tungsten, is presented in fig.3. As is evident from this drawing, heat conductiin decreases with rise in temperature, which is in conformity with Osborn 2 results.
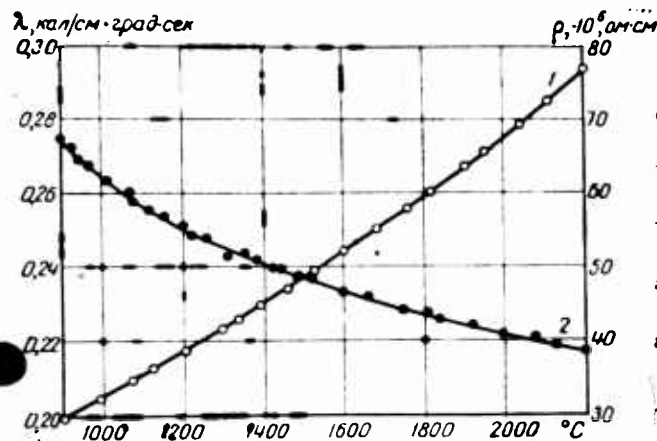

Fig.3. Temperature dependence of heat conduction lambda (curve 2) and specific electric resistance rho (curve 1) of tungsten.

But in our case the heat conduction/temperature dependence is not subject to linear law. According to the absolute value the coefficient of heat conduction is close to heat values, obtained by Worting, Swicker and Forsybe 1 and Osborn 2 and is in no agreement with data listed in literature 3,4, which in our opinion are erroneous. The specific electric resistance (curve 1 fig.3) with the rise in temperature increases from 29.8 (900)to 77.3 microhms. cm (2200).

From the obtained data on heat-and electro-conduction of tungsten were calculated the values of the Wiedeman-Frantz ratio for various temperatures over the entire investigated region. The Lorentz number exceeds the theoretical value and depends slightly upon temperature (see table 2).

Table 2.

$T, °C$	$L \cdot 10^8, \frac{\text{вт} \cdot \text{ом}}{\text{град}}$	$T, °C$	$L \cdot 10^8, \frac{\text{вт} \cdot \text{ом}}{\text{град}}$
900	2,91	1600	2,72
1000	2,83	1700	2,71
1100	2,79	1800	2,72
1200	2,74	1900	2,72
1300	2,73	2000	2,73
1400	2,72	2100	2,74
1500	2,72	2200	2,77

The temperature dependence of the heat conduction coefficient for graphite is shown in fig.4. By the order of magnitude our data are in good xxxxx agreement with the literature data 3 .A more accurate comparison has no sense because the properties of graphite depend to a large degree upon the method of its derivation etc. The specific electric resistance of graphite rise with the rise in temperature and in the zone of high temperatures (above 1500 C) it changes in accordance with the law close to linear.

The obtained experimental results on thethermal progress of heat conduction coefficients of tungsten and graphite are well described by curves

$$\text{lambda} = a - bT - cT^2$$

When the heat conduction coefficient of tungsten is determined by the mathematical method in the range of temperatures of from 900 - 2200 C it is possible with a sufficient degree of accuracy to use the dependence

$$\text{lambda} = 0.361 - 1.17 \cdot 10^{-4}\,T - 2.32 \cdot 10^{-8}\,T^2$$

To calculate heat conduction for graphite at temperatures of 900 - 2000°C one can recommend the following formula

$$\text{lambda} = 0.12 - 0.547 \cdot 10^{-4}\,T - 1.42 \cdot 10^{-8}\,T^2$$

For the purpose of comparison table 3 contains values of heat conduction coefficient for tungsten and graphite at various temperatures,obtained experimentally and calculated by above mentioned formulas.

Table 3

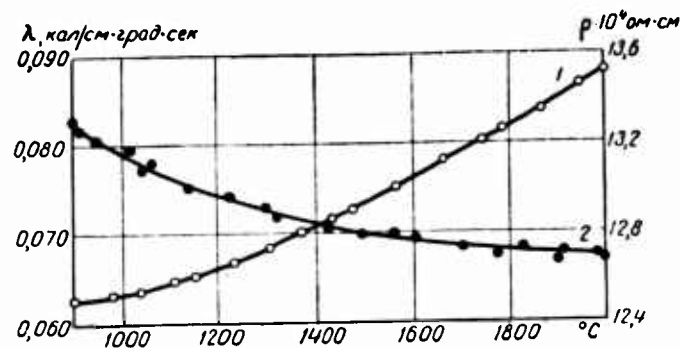| Temper. C	Heat conduction (cal/cm.degree.sec)			
	Tungsten		Graphite	
	Exper.	Calcul.	Exper.	Calcul.

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Figure 4. Temperature Dependence of Heat Conduction λ (curve 2) and Spec. Electric Resistance ρ (Curve 1) of Graphite.

Table 3 cont'd

900	0.275	0.274	0.0825	0.0824
1000	0.265	0.267	0.0795	0.0796
1100	0.256	0.260	0.0765	0.0771
1200	0.251	0.254	0.0745	0.0749
1300	0.245	0.249	0.0728	0.0730
1400	0.242	0.242	0.0714	0.0714
1500	0.238	0.238	0.0705	0.0700
1600	0.234	0.233	0.0693	0.0689
1700	0.230	0.228	0.0685	0.0682
1800	0.228	0.226	0.0680	0.0678
1900	0.225	0.222	0.0677	0.0676
2000	0.222	0.219	0.0675	0.0675
2100	0.218	0.217	—	—
2200	0.216	0.215	—	—

Conclusions

1. The described installation allows to determine in an independent way, in one and the very same conditions with sufficient degree of accuracy the heat and elcyro-conduction of metals and alloys in a wide range of temperatyres.

2. The heat conduction coefficients of tungsten and graphite decrease with the rise in temperature, and their progression is well described by curves of the second magnitude over the entire investigated range.

3. The Lorentz number for tungsten in the range of temperatures of 900-2200° C are above the theoretical value and depends loosely upon temperature.

Academy of Sciences Ukr-SSR   Submitted, July 22, 1960
Phys-Techn.Institute

Literature

1. Slavinskiy,M.P.Phys-Chem.Properties of Elements (Fiziko-Khimicheskiye Svoystva Elementov) Moscow,1952.

2...of English origin.

3. Technology of High Temperatures (Foreign Literature) 1959

4. Filyand,M.A; Semenova,Ye.I.Properties of Rare Elements (Svoystva Redkikh Elementov) Moscow 1953

5. Lebedev, V.V. (in print)

6. of English origin.